[0047] Transducers comprising a polyphosphazene elastomer film disposed between two electrodes have been described. In contrast to the acrylate and silicone polymer films, the polyphosphazene elastomers have a combination of both good elastic properties as well as suitable tear strengths. For use in transducer applications, elastomers having low modulus, high elongation, high dielectric constant, low dielectric losses, good elastic characteristics and high electric field strength are desired. The polyphosphazene films can have tear strengths of about 25.4 kiloNewtons/meter (kN/m), while for a comparable silicone elastomer the tear strength is about 11 kN/m. The polyphosphazene films have a dielectric constant of about 6 to about 8 at 1 kHz, an electric field strength of up to about 132 V/μm, a low elastic modulus of the order of 1 MPa, and high elongation of greater than or equal to 500%. Actuators comprising the polyphosphazene films can have area strain values of greater than or equal to 80%, and possibly even higher. This combination of properties makes the polyphosphazene films suitable for a wide range of high-performance actuator applications such as robotics, loudspeakers and prosthetic devices.

[0048] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

[0049] What is claimed is:

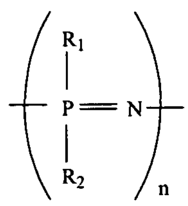
1. A transducer comprising:

a first electrode;

a second electrode;

and an elastomeric film disposed therebetween;

wherein the elastomeric film comprises a polyphosphazene having Formula (1):



(1)

wherein each R_1 and R_2 is independently selected from chloro; bromo; iodo; substituted and unsubstituted alkyl, alkenyl, or alkynyl; aralkyl; alkaryl; aryl; heteroalkyl; heteroaryl; cyano; amino acid ester; carboxylic acid ester; oxyaryl; alkoxy; haloalkoxy; fluoroalkoxy; oxy(aliphatic)hydroxyl; oxy(alkyl)hydroxyl; oxyalkaryl; oxyaralkyl; thioaryl; thioalkyl; thioalkaryl; aliphatic ketone; aryl ketone; phosphine oxide; phosphoryl; sulfone; and sulfoxide; and wherein n is about 20 to about 50,000.

2. The transducer of Claim 1, wherein R_1 and R_2 are different.

3. The transducer of Claim 2, wherein R_1 is OCH_2CF_3, and R_2 is $OCH_2CF_2CF_3$, $OCH_2CF_2CF_2H$, $OCH_2(CF_3)_2$, $OCH_2CF_2CF_2CF_3$, $OCH_2CF_2CF_2CF_2CF_2$, or a combination comprising one or more of the foregoing substituents.

4. The transducer of Claim 1, wherein the polyphosphazene comprises allyl crosslinking substituents, vinyl crosslinking substituents, or a combination of one or more of the foregoing substituents.

5. The transducer of Claim 4, wherein the crosslinking substituent is a eugenoxy substituent, a 2-allyl phenoxy substituent, or a combination comprising one or more of the foregoing substituents.

6. The transducer of Claim 1, wherein the elastomeric film has a thickness of about 5 micrometers to about 250 micrometers.

7. The transducer of Claim 1, wherein the elastomeric film is a multilayer film.

8. The transducer of Claim 1, wherein the first electrode, the second electrode, or both, is a compliant electrode.

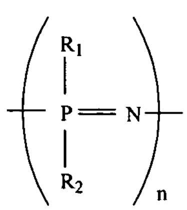
9. The actuator of Claim 8, wherein the compliant electrode comprises a conductive grease, a colloidal suspension, carbon nanotubes, carbon fibrils, a metal layer, a conductive polymer, or a combination of one or more of the foregoing materials.

10. A method of making a transducer comprising:

disposing a first electrode on a first side of an elastomeric film, and

disposing a second electrode on a second side of the elastomeric film opposite the first side,

wherein the elastomeric film comprises a polyphosphazene having Formula (1):



(1)

wherein each R_1 and R_2 is independently selected from chloro; bromo; iodo; substituted and unsubstituted alkyl, alkenyl, or alkynyl; aralkyl; alkaryl; aryl; heteroalkyl; heteroaryl; cyano; amino acid ester; carboxylic acid ester; oxyaryl; alkoxy; haloalkoxy; fluoroalkoxy; oxy(aliphatic)hydroxyl; oxy(alkyl)hydroxyl; oxyalkaryl; oxyaralkyl; thioaryl; thioalkyl; thioalkaryl; aliphatic ketone; aryl ketone; phosphine oxide; phosphoryl; sulfone; and sulfoxide; and wherein n is about 20 to about 50,000.

11. The method of Claim 10, wherein R_1 and R_2 are different.

12. The method of Claim 11, wherein R_1 is OCH_2CF_3, and R_2 is $OCH_2CF_2CF_3$, $OCH_2CF_2CF_2H$, $OCH_2(CF_3)_2$, $OCH_2CF_2CF_2CF_3$, $OCH_2CF_2CF_2CF_2CF_2$, or a combination comprising one or more of the foregoing substituents.

13. The method of Claim 10, wherein the polyphosphazene comprises allyl crosslinking substituents, vinyl crosslinking substituents, or a combination of one or more of the foregoing substituents.

14. The method of Claim 13, wherein the crosslinking substituent is a eugenoxy substituent, a 2-allyl phenoxy substituent, or a combination comprising one or more of the foregoing substituents.

15. The method of Claim 10, wherein the elastomeric film has a thickness of about 5 micrometers to about 250 micrometers.

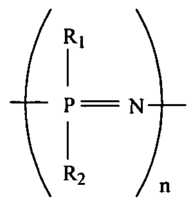
16. The method of Claim 10, wherein the elastomeric film is a multilayer film.

17. The method of Claim 10, wherein the first electrode, the second electrode, or both, is a compliant electrode.

18. The method of Claim 17, wherein the compliant electrode comprises a conductive grease, a colloidal suspension, carbon nanotubes, carbon fibrils, a metal layer, a conductive polymer, or a combination of one or more of the foregoing materials.

19. A method of converting between electrical energy and mechanical energy, comprising:

applying an electric charge to a transducer comprising a first electrode, a second electrode, and an elastomeric film disposed there between; wherein the elastomeric film comprises a polyphosphazene having Formula (1):



(1)

wherein each R_1 and R_2 is independently selected from chloro; bromo; iodo; substituted and unsubstituted alkyl, alkenyl, or alkynyl; aralkyl; alkaryl; aryl; heteroalkyl; heteroaryl; cyano; amino acid ester; carboxylic acid ester; oxyaryl; alkoxy; haloalkoxy; fluoroalkoxy; oxy(aliphatic)hydroxyl; oxy(alkyl)hydroxyl; oxyalkaryl; oxyaralkyl; thioaryl; thioalkyl; thioalkaryl; aliphatic ketone; aryl ketone; phosphine oxide; phosphoryl; sulfone; and sulfoxide; and wherein n is about 20 to about 50,000.;

producing material strain in the elastomeric film.

20. The method of Claim 19, wherein R_1 is OCH_2CF_3, and R_2 is $OCH_2CF_2CF_3$, $OCH_2CF_2CF_2H$, $OCH_2(CF_3)_2$, $OCH_2CF_2CF_2CF_3$, $OCH_2CF_2CF_2CF_2CF_2$, or a combination comprising one or more of the foregoing substituents.

21. The method of Claim 19, wherein the polyphosphazene comprises allyl crosslinking substituents, vinyl crosslinking substituents, or a combination of one or more of the foregoing substituents.

22. The method of Claim 19, wherein the first electrode, the second electrode, or both, is a compliant electrode.

23. The method of Claim 19, wherein pre-strain is applied to the actuator in one linear direction prior to applying an electric charge.